400 WATTS, AND COASTS ALONG

STEP-BY-STEP INSTRUCTIONS FOR BUILDING G0DZU'S POWERFUL HF BAND 4CX1000A LINEAR AMPLIFIER WHICH STANDS UP AGAINST ANY "JAP-PACK"

For me, Amateur Radio is about experimentation and discovering the best way of achieving good results with minimum expenditure and resources. This often means that a lot of time needs to be spent hunting down that rare component and trying out new circuit ideas. This is all part of the enjoyment of the hobby. There are, alas, few major construction projects these days which allow you to feel that what has been achieved will work as well as that 'Japanese black box' but one of the exceptions to this is the hf linear amplifier, where the valve still reigns supreme.

This was to be a once-only project so the final design needed to have high reliability with excellent performance to match. The power rating was an important decision, considering the possibility that the legal limit may be increased in the future.

In the process of constructing this amplifier, a lot of information has been accumulated which should be of use to other amateurs wishing to construct a similar project, as well as being of general interest. I have attempted to write this article in such a way that it emphasises the pitfalls, which are not always apparent from reading text books. There are also a number of features which depart from normal practice.

I make no excuse for the size of the finished amplifier, which consists of two 19in by 10·5in racks in a floor mounted cabinet. The glowing reports of excellent signal quality more than compensate for the size and weight. Besides which my wife Tricia regards it as a "nice piece of furniture", (perhaps this is because she is also licensed). On a more sobering note, this project should only be attempted if you feel confident in working with high voltage circuits.

It must be emphasised that the voltages involved should be treated with considerable respect. Do not be tempted to work on the live circuit, particularly if you are tired, for this is when accidents can occur. If you are making any adjustments inside the cabinet, always discharge the capacitors with a large resistor first and then a shorting bar, before touching anything.

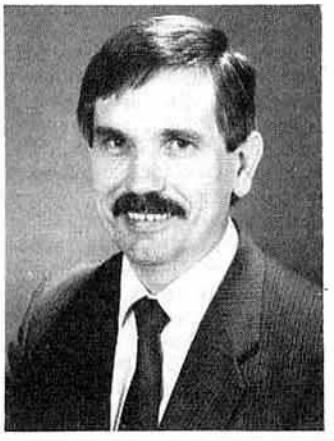
THE CHOICE OF VALVE

In studying valve specifications, the 4CX1000A beam tetrode appears to be an ideal choice. They are capable of achieving high gain with excellent linearity and were specifically designed for use in Class AB1 rf linear amplifiers.

Cost is always an important consideration. I have obtained a stock of twelve ex-equipment valves from various sources at reasonable prices. Eight of these were in excellent condition and three suffered from high negative screen current but were still usable. Only one was useless owing to a short circuit between the grid and screen. It has since been discovered that the grid construction of English Electric valves is not as mechanically rugged as Eimac. When buying secondhand it is advisable to check for obvious faults before handing over the money.

I noted comments in past issues of *Rad Com* which emphasise the care required to protect the 4CX series valves from damage, particularly with regard to the switch-on procedures. Although a number of features have been incorporated which limit the possibility of damage, the design has been kept as simple as possible.

As I had accumulated a good stock of valves, it was decided to sacrifice one of them in an attempt to discover what damage can be caused by a range of abuses. As it turned out, this valve remained in good working order, even when on one occasion a screen to anode flashover occurred.



Peter Barker has been interested in radio and electronics since his school days in the sixties and became licenced in 1978 with the callsign GW80SY. He moved from North Wales to Southern England in 1979. With the help of fellow amateurs and morse classes at the Salisbury Radio and Electronic Society, he obtained his A licence in January 1986. Much of his radio equipment is home constructed and the station is also operated by his wife Tricia under her own callsign G0HLA. Professionally, Peter is Technical Director of a Romsey-based company who manufacture capacitors and mains filters. He has several patents to his name and is also a member of UK and International committees involved with the preparation of safety and performance standards.

AMPLIFIER CONNECTIONS

The circuit of the complete amplifier chassis is shown in Fig 1. Connections are made to the power supply chassis by plugs and leads. The high voltage plug (A) is the main ht supply and (C) is the ht negative which provides a return to ground through an ammeter M1.

There is an interlock link (D) and (E) which prevents a latching relay on the power supply chassis from holding in should, the plug carrying (B) to (E) become disconnected. The mains plug (F) to (H) is also connected to the power supply chassis. RF input (L) and Output (M) together with (I), (J) and (K) are connected to the relay changeover circuit.

THE AMPLIFIER GRID COMPARTMENT

Input (L) is connected to a low pass filter circuit C32 and L1. This is necessary to compensate for the high input capacitance of the 4CX1000A (81pF) which would otherwise result in high VSWR at 28MHz.

A passive grid arrangement was chosen for its simplicity and inherent stability. No neutralisation is required provided that the leads to the grid are kept as short as possible.

Power from the driver transmitter output is terminated in the 50Ω resistor R5. This resistor is positioned in the main air flow and needs to be of sufficient wattage rating to dissipate the maximum input drive of 30W. If your transmitter delivers 100W and is difficult to adjust to 30W then you can use the power attenuator (Fig.6).

RF voltage is fed to the grid of the 4CX1000A through a coupling capacitor C4 and bias voltage is applied through RFC4. As the amplifier operates in class AB1 the grid is driven by voltage only and under normal conditions there should be negligible current flow.

The connections to the valve starting with the bottom set of fins are: heater, heater/cathode, control grid and screen. Heater decoupling capacitors C5, C6 and C7 are connected across the first and second set of base terminals. It is necessary to earth the second set by soldering 3 separate wires direct to ground.

The valve base has a built-in bypass capacitor Cx and it is important to protect this from damage due to disconnection or failure of the screen supply, which would otherwise result in the screen assuming the same potential as the anode, probably destroying the valve in the process. For this reason I have placed three separate screen supply bleed resistors directly across the screen terminals of the valve base and these are kept cool by the main air flow. There is also a transient voltage protector connected from screen to ground as it is possible for negative screen current to exceed the current drawn by the resistors. All supply leads are decoupled to ground through 1000pF lead-through capacitors.

HEATER, GRID AND SCREEN SUPPLIES

A single transformer is used for the heater, grid and screen circuits. This could be either a secondhand transformer, dismantled and rewound with new secondary windings or a kit transformer. Toroidal transformers are not recommended, as the low leakage reactance would result in high switch-on surges and would subject the valve heater to excessive thermal shock. I used a 200VA RS Components transformer system. Information on how to wind the secondary to produce 270V – 0 – 270V, 20V and 6V is detailed in the parts list.

The Eimac recommended heater supply is 6V+ or −5 per cent at 8A to 10A. The heater voltage across the base with the valve in place measured 5·8V with 240V primary and this is ideal for long valve life. The heater voltage may be adjusted slightly by altering the length or gauge of the connecting wires between the power supply and valve base. Adjustments should be made using an accurate digital voltmeter making appropriate compensation for the mains voltage at time of measurement (in the UK the 240V nominal mains can vary between 226V and 254V).

The 270V – 0 – 270V ac is full-wave rectified by diodes D7 and D8 and smoothed by C20 and C21 to provide a positive supply for the screen

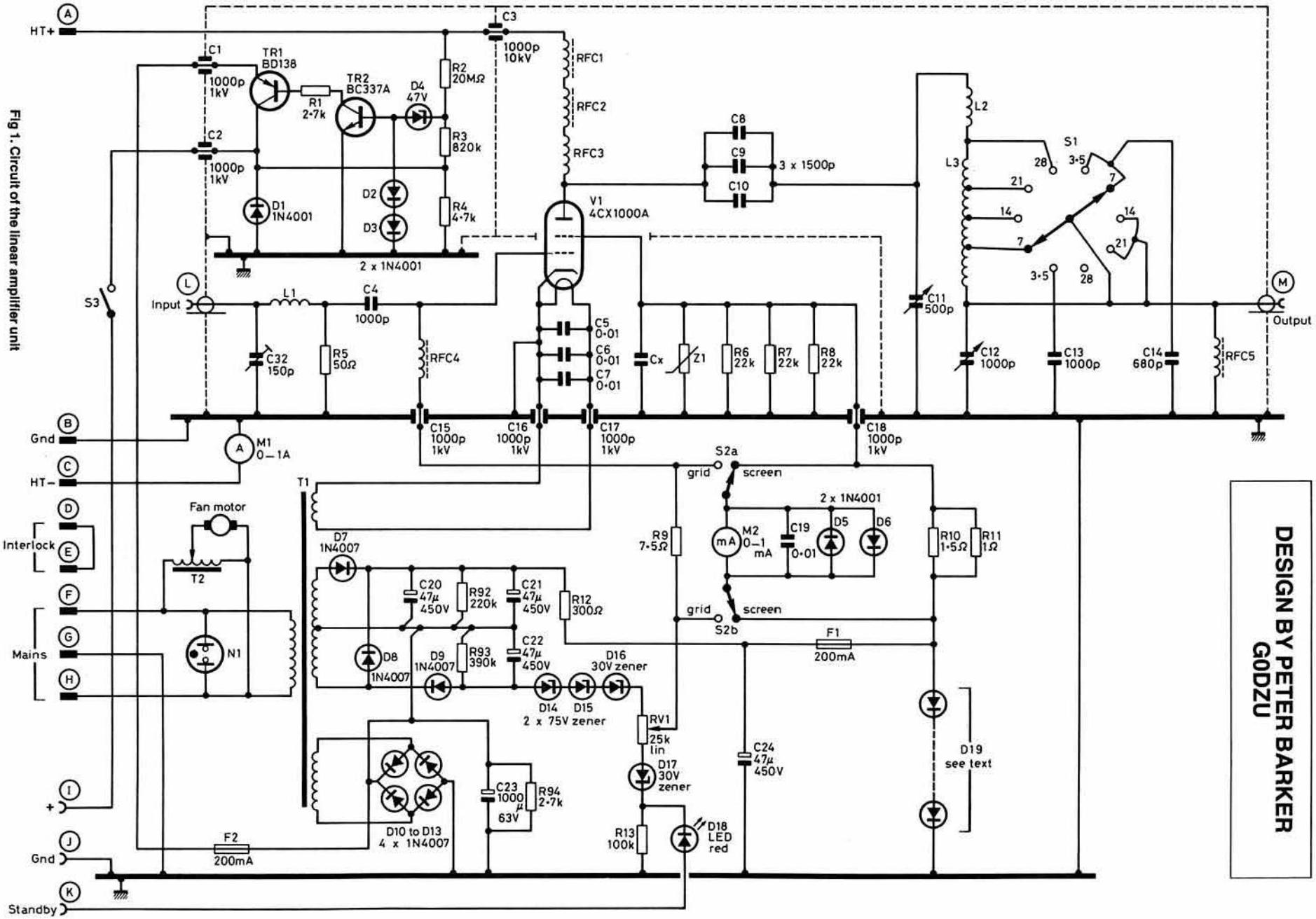


Fig 1. Circuit of the linear amplifier unit

circuit. The same winding is half wave rectified by D9 and smoothed by C22 to provide a negative supply for the grid base. A 28V DC supply is derived from the 20V winding, bridge rectifier D10 to D13 and capacitor C23. This supply powers the changeover relay circuit shown in Fig 7. The 28V supply is also connected in series with the grid bias and screen supply to increase the voltage to R12 and reduce the voltage to O14.

The required grid bias voltage is approximately −60V during operation and −150V during standby. To reduce from −150V to −60V the standby terminal is connected to ground causing the led, D18 to illuminate. The bias is adjusted with RV1 which is part of the potential divider chain D14, D15, D16 and D17. The D17 zener diode voltage was chosen to provide the greatest stability of standing anode current with normal fluctuations in mains voltage. Reducing the D17 zener diode voltage causes a reduction in anode current with increased mains voltage. The diode referred to in the parts list was found to be optimum.

Stabilisation of the screen supply caused many problems during the development of this amplifier. Various circuits were tried including power transistor regulators and series connected 56V 20W zener diodes. These either produced poor linearity or gave reliability problems during fault conditions. The zener diode arrangement also suffered from poor thermal stability, ie as they became hot the screen voltage increased due to positive temperature coefficient. The 4CX1000A has a tendency to "pull" the screen supply towards the anode potential producing further temperature rise and although this problem could be reduced to manageable proportions if a large heatsink is placed on the zener diodes, I decided to search for an alternative solution.

It became clear that the 4CX1000A requires a low impedance screen supply which must source or sink large amounts of current. The final arrangement consisted of a bank of 420 diodes (D19), series connected in their forward conducting mode, giving a forward voltage drop of 325V. This directly replaced the zener diodes. On the face of it this may appear to be an expensive and laborious approach, but suitable diodes such as the IN4001 cost only 50 per cent more than my zener diodes.

Construction of the supply

Construction is easy using 0·1in matrix board assembled in a zig-zag pattern as illustrated in Fig 2. The diode assembly was resin potted in a shallow box made from aluminium sheet; this was then screwed to the chassis near the blower inlet. A number of taps on the diode bank near one end were included to provide adjustment of the screen voltage.

The finished screen supply gave all the properties required with rock solid stability, the ability to withstand large current surges without damage and the advantage of negative temperature coefficient which causes the valve to reduce power should overheating occur. Note that the screen supply fuse F1 is on the power supply side of the diode bank. This is to ensure that the screen is firmly tied down by the diodes even if the fuse should blow. Valve damage may occur if the screen is not protected against excessive current resulting from bias failure. F1 must be a fast blow fuse of 200mA rating. Many of the fault conditions simulated have caused F1 to blow without damage to the valve, but only because the correct rating has been used.

The capacitor C24 was found to improve linearity slightly by decoupling the screen supply to ground at audio frequencies. R12 was adjusted to 300Ω to provide a standing current of 100mA through F1. As 40mA is drawn by the screen bleed resistors, the meter, when switched to the screen position will be offset by this amount allowing both −ve and +ve screen current to be monitored. The meter is scaled to read −40 to +60mA screen current and 0 to 10 mA grid current.

It may be necessary to adjust R9 and R10/R11 to calibrate the meter and I found it easier and safer to carry out this calibration against an accurate multimeter before installing the resistors in the circuit. It may appear as if I have the connections from R9 to S2a and S2b the wrong way round but during tests on my "sacrificial valve" I found that reverse grid current occurred with excessive input drive and this was the only condition that produced grid current.

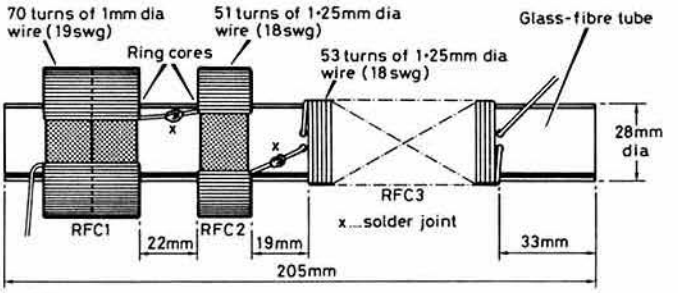


Fig 3. Anode choke

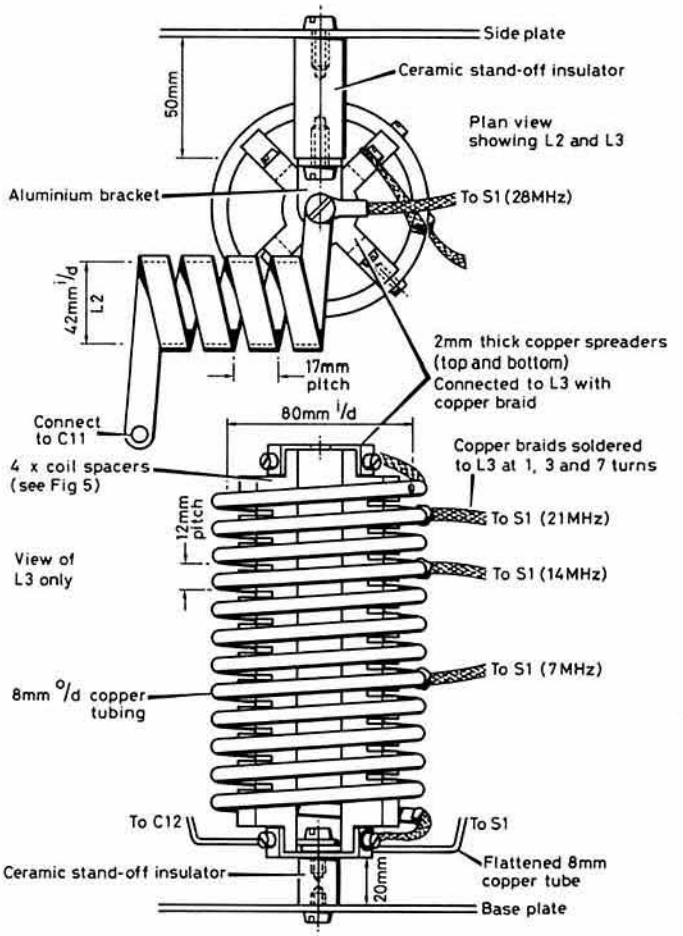


Fig 4. PI tank coils

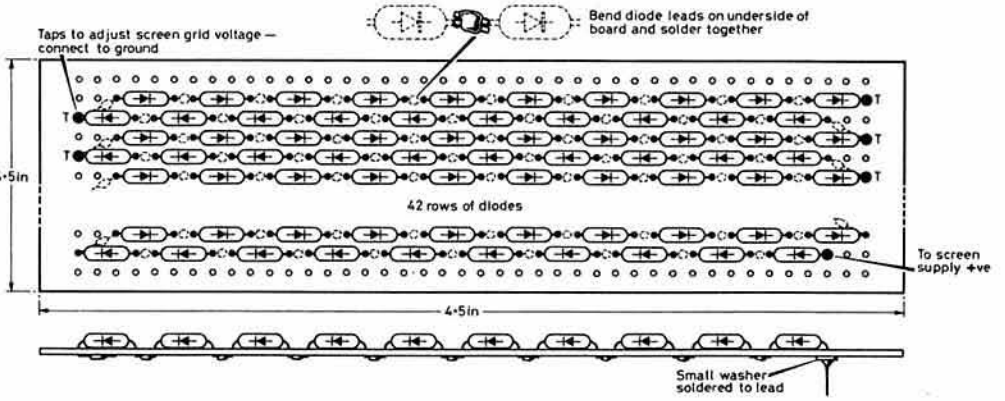

Taps to adjust screen grid voltage — connect to ground
Bend diode leads on underside of board and solder together
4·5in
42 rows of diodes
To screen supply +ve
4·5in
Small washer soldered to lead

Fig 2. Diode bank for screen supply

ANODE COMPARTMENT

The anode circuit is a conventional arrangement but construction of some of the components differs from normal practice. The anode choke proved to be the most troublesome item. The first design tried was wound by the traditional method of gaps between progressively shorter sections. This was checked by a spectrum analyser which revealed that there were six resonant frequencies, but despite careful adjustment of the turns to prevent resonance within the amateur band this was shown to be unsuitable as overheating occured at the higher frequencies. A second choke was wound with no gaps, reducing the number of resonances to five. This performed better than the first choke, but again fell short of an acceptable solution as overheating still occurred

Multi-band choke – the solution

After a great deal of experimenting with different diameter formers and various wire gauges, it became evident that it was relatively easy to design a choke for only one band, but the difficulty arose when a single choke was required to cover all bands. The problem was finally resolved by producing three independent chokes mounted on the same former. This is illustrated in Fig 3.

A low inductance choke RFC3 was wound on one end of a glass fibre tube; this was adjusted to give high impedance on 21 and 28MHz. A second choke RFC2 was wound on a low permeability ring core which was salvaged from a junk Decca Voyager marine radio. The core fitted snugly over the opposite end of the glass fibre tube. Adjustments were made to RFC2 at 14MHz with RFC3 and RFC2 connected in series. A third choke RFC1 was added to cater for the 3·5MHz and 7·0MHz bands. This consisted of two of the cores used for RFC2. The final assembly was checked on the spectrum analyser and was found to have only two resonant frequencies. With the choke in place the amplifier was driven to full output into a dummy load for 10 minutes on each band in turn. The maximum temperature of any of the chokes did not exceed 85°C.

"Mini-bore" coils

Connection to the 4CX1000A anode was made with an 80mm diameter clamp constructed from flattened 8mm od "minibore" tubing to form a copper strip. This tubing is readily available from DIY stores. One end of the strip extended by 80mm to enable connection to the three capacitors C8, C9 and C10. A second strip made by the same method connected the other end of the capacitors to C11 and L2. Construction details for the pi tank coil are shown in Fig 4. L2 and L3 are also constructed from 8mm od "minibore" copper tubing.

For L2, a 750mm length of tubing is flattened in a vice to form a 12mm wide strip which is then wound on a temporary 42mm former. For L3 a four metre length of tubing is fully filled with water and each end flattened and folded over twice. Wind the tube around an 8φmm former and then cut off the ends, to produce a neat coil. The water is simply a means of preventing the tube from collapsing. L3 is mounted at right angles to L2 on ceramic insulators. Four internal supports are required for L3, one of which is shown in Fig 5. The remaining three have the castellations positioned 3mm, 6mm and 9mm off centre to match the coil spiral.

A vacuum variable capacitor was chosen for C11 because of the much reduced size and lower minimum capacitance compared to air spaced types. If an air spaced capacitor was used it is doubtful whether the amplifier could function on the 28MHz band. A 10kV capacitor was used but a 5kV would suffice. A vacuum variable capacitor was also chosen for C12 but this is not essential as the voltage at this point is less than 250V. A multi-section air spaced capacitor of the type used in valved receivers would be suitable. Connection between S1 and the capacitors C13 and C14 were made using copper braid stripped from UR67 cable. To reduce losses, the braid was doubled by stretching one length and threading it through the middle of another. RFC5 is not critical, but must be capable of carrying ht fault current. Its only function is to cause the ht fuse to blow in the event of capacitors C8, C9 or C10 becoming short circuit, thus preventing dangerous dc voltage from reaching the output.

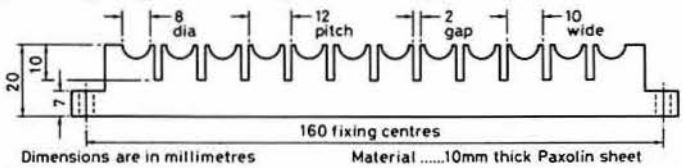
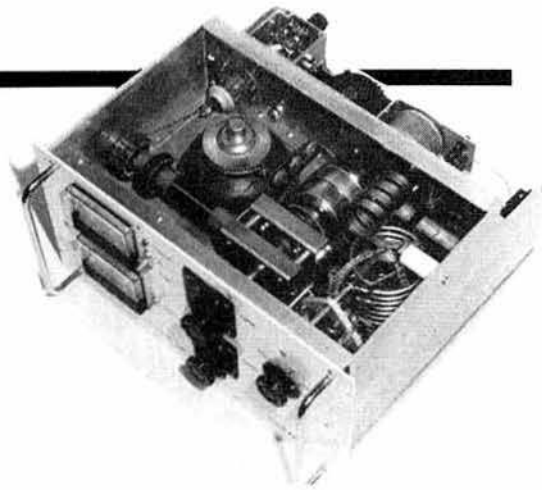
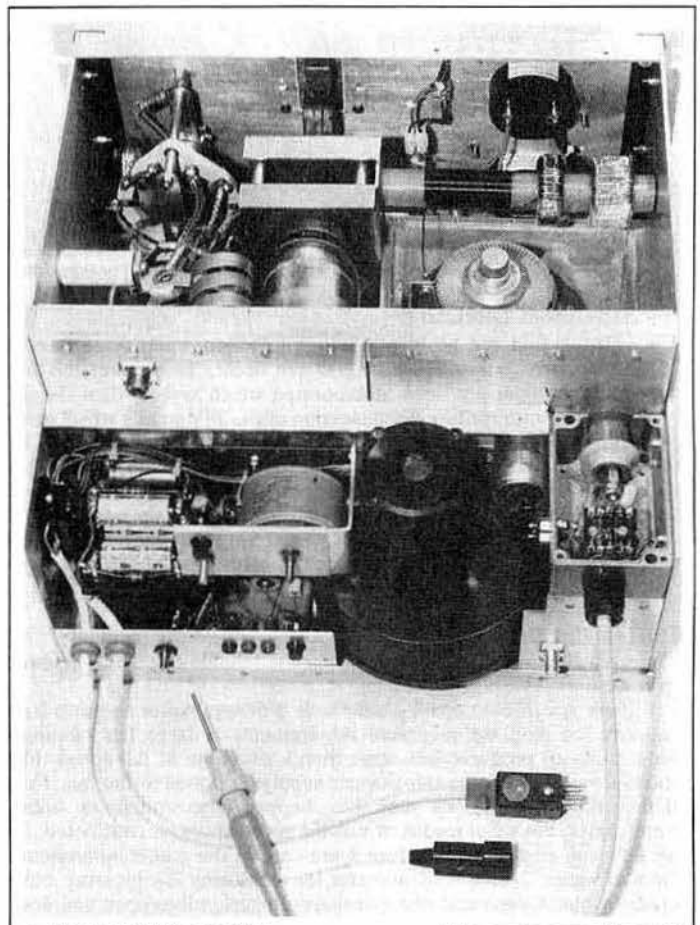


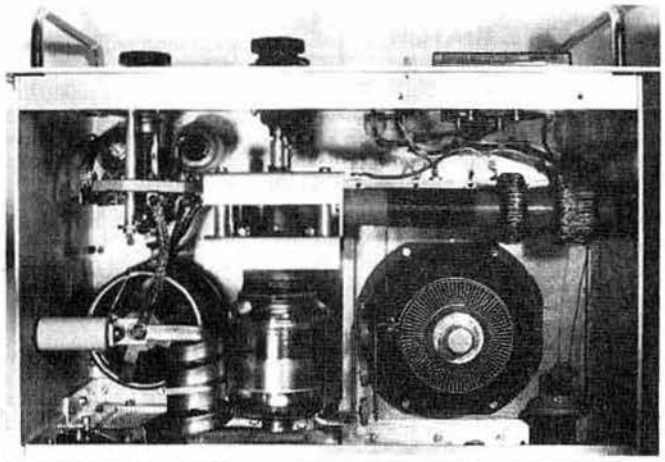
Fig 5 One of the four spacers for L3

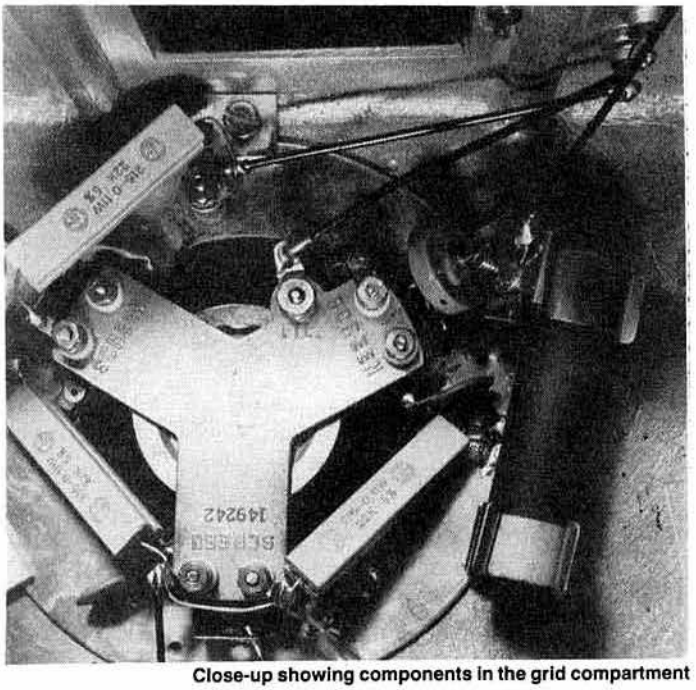




▲ Rear view of the amplifier

The anode compartment ▼





Close-up showing components in the grid compartment

HT SENSING CIRCUIT

The valve should not be biased into conduction when there is no ht present or damage to the screen grid can occur. To prevent this from happening a circuit has been incorporated which senses when the ht is below 800V. This results in disconnection of the 28V supply which in turn prevents the amplifier from being operated. The sensing circuit is in a separate screened box which contains one side of the high voltage leadthrough capacitor C3. The circuit, consisting of TR1, TR2, D1 to D4 and R1 to R4 is built on a tagboard. Feedback between the output and R4 ensures clean switching action. The linear amplifier may be manually disabled by means of switch S3 which is connected in series with the output of the sensing circuit.

THE COOLING FAN

The size of the cooling fan is important for reliable operation. It should have a minimum capacity of 25cfm.

If there is sufficient space available it is always better to use a larger capacity fan than the minimum requirement. A large fan running at reduced speed produces less noise than a small fan at full speed. Fig 1 shows a variable voltage transformer supplying power to the fan. I used this method because my junk box happened to contain a suitable transformer, but other means of varying speed could be considered. The air flow was adjusted to produce a pressure in the grid compartment of 5mm of water. A simple manometer for measuring low pressure can be made by placing one end of a transparent plastic tube (open end down) alongside a ruler in a jar of water. Displacement of water in the tube can then be measured.

INPUT ATTENUATOR

Construction details for a 6dB power attenuator are given in Fig 6. This will enable the output from a 100W transceiver to match the 25/30W input required by the linear amplifier. The only component worthy of comment is the 50Ω solid resistor which was obtained from one of the stalls at a recent rally. SWR of the assembled unit is better than 1·1:1 at 30MHz. □

NEXT MONTH

Full details for constructing the power supply, plus instructions for firing up and aligning the linear amplifier

COMPONENTS LIST – AMPLIFIER

R1	2·7kΩ 0·25W
R2	20MΩ 2W 3kV minimum, or 6-off, series connected 3·3MΩ 0·5W carbon film
R3	820kΩ 0·25W
R4	4·7kΩ 0·25W
R5	50Ω 30W solid carbon (see text)
R6, 7, 8	22kΩ 11W wire sound
R9	7·5Ω 3W wire wound (see text)
R10	1·5Ω 3W wire wound (see text)
R11	1·0Ω 3W wire wound (see text)
R12	300Ω 11W wire wound
R13	100kΩ 1W
R92	220kΩ 2W
R93	390kΩ 1W
R94	2·7kΩ 1W
RV1	25kΩ 3W wire wound, lin, pot
Z1	Transient voltage protector Z250G or equiv
C1, 2, 15, 16	1000pF 1000V lead through
17, 18	1000pF 10kV lead through
C3	1000pF 1000V ceramic
C4	0·01µF 1000V ceramic
C5, 6, 7, 19	1500pF 10kV ceramic
C8, 9, 10	500pF 5KV min. Jennings vacuum variable
C11	1000pF 250V min. Jennings vacuum variable or air spaced variable (see text)
C12	1000pF 10kV screw mounted ceramic
C13	680pF 10kV screw mounted ceramic
C14	47µF 450V electrolytic
C20, 21, 22, 24	1000µF 63V electrolytic
C23	150pF low voltage air spaced variable
C32	IN4001
D1, 2, 3, 5, 6	47V 1·3W zener
D4	IN4007
D7, 8, 9, 10, 11	75V 5W zener
12, 13	30V 1·3W zener type BZX61
D14, 15	Red LED indicator
D16, 17	420 IN4001 or similar diodes – see text
D18	BD138
D19	BC337A
TR1	4CX1000A Eimac or English Electric
TR2	28mm dia × 205mm glass fibre tube. 1·0mm (19swg) enam copper. 1·25mm (18swg) enam copper. 3 off 52mm OD × 31mm ID × 14mm wide, Low loss, Amidon ring core (AL=14nH) (see text)
V1	470µH choke
RFC1, 2, 3	2·5mH 2A choke
RFC4	200VA transformer system (RS Components stock no 208-579). 568+568t, 0·2mm (35/36swg) enam copper, 42t, 0·25mm (33swg) enam copper. 13t, 4 × 1·25mm (18swg) wound together. Windings separated with glass fibre tape. Output 270V-0-270V, 20V and 6V respectively.
RFC5	0·5A 240V variable or multi tapped auto transformer or variac (see text).
T1	5t, 14mm ID, 20mm long 1·5mm (16swg) enamel copper.
T2	4t, 42mm ID, 17mm pitch. Made from flattened 8mm OD, "Minibore" copper tubing.
L1	12t, 80mm ID, 12mm pitch. Made from 8mm OD "Minibore" copper tubing.
L2	200mA fast blow fuse
L3	Heavy duty RF type switch, double pole 5 way (see text)
F1, F2	DPDT toggle switch
S1	SPST toggle switch
S2	240V neon indicator
S3	0 – 1A moving coil meter
N1	0 – 1mA moving coil meter
M1	centrifugal type, 25CFM minimum
M2	Valve base – Eimac SK800B, SK810B or SK890B
FAN	
Miscellaneous:	

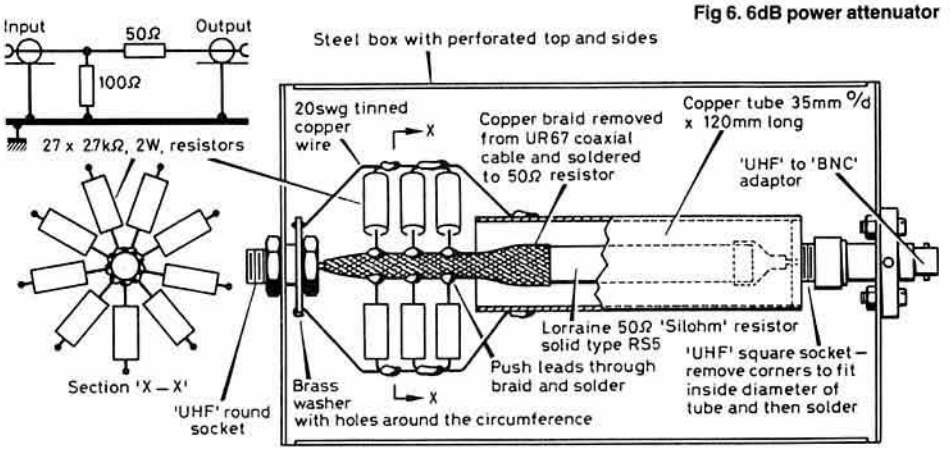

Input
50Ω
Output
100Ω
27 x 27kΩ, 2W, resistors
Section 'X – X'
'UHF' round socket
Steel box with perforated top and sides
20swg tinned copper wire
X
Copper braid removed from UR67 coaxial cable and soldered to 50Ω resistor
Copper tube 35mm ⌀ x 120mm long
'UHF' to 'BNC' adaptor
Lorraine 50Ω 'Silohm' resistor solid type RS5
Push leads through braid and solder
'UHF' square socket – remove corners to fit inside diameter of tube and then solder
Brass washer with holes around the circumference
X

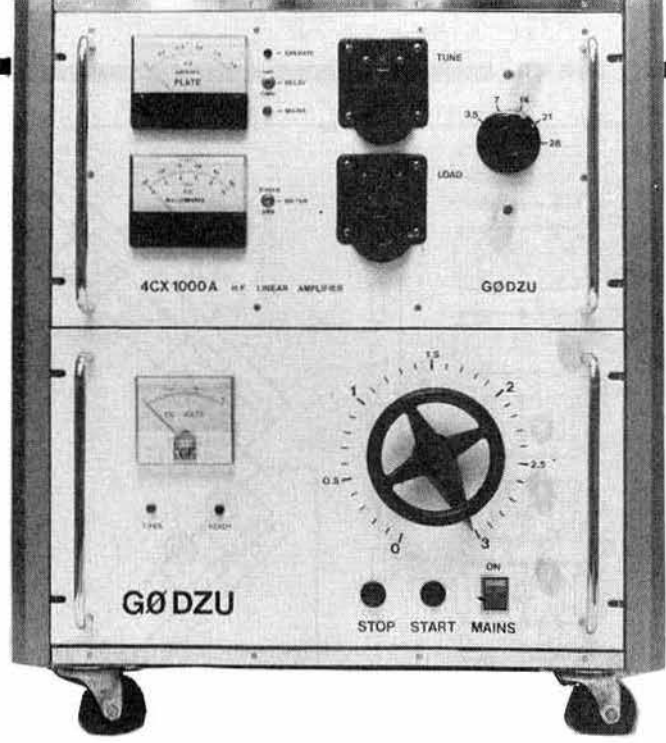
Fig 6. 6dB power attenuator

G0DZU'S 400-WATT HF LINEAR

PART TWO: THE POWER SUPPLY

CONTINUING THE INSTRUCTIONS FOR BUILDING A 4CX1000A LINEAR WHICH IS CAPABLE OF RUNNING A VERY COOL 400 WATTS INDEFINITELY. PART ONE APPEARED IN JUNE

BY PETER BARKER, G0DZU



The ht power supply circuit is shown in Fig 6. Mains voltage is supplied, through a double pole switch S4 to a latching circuit RLA, S5 and S6. The purpose of the latching arrangement is to prevent power from being immediately restored should the mains be momentarily interrupted. It also prevents the power supply from functioning should the ground connection to the amplifier become disconnected which could otherwise result in high voltages appearing between the amplifier chassis and power supply chassis. S6 energises the latching relay RLA which supplies 240V mains to the amplifier through socket (F) (G) (HG) and also starts the timing sequence.

Timer A allows the valve heater to reach working temperature after approximately five minutes. Timer B is then energised and power is supplied to the transformer through resistor R15 which prevents high switch-on surges. After a further 10 seconds R15 is shorted and full mains voltage is applied to T3.

A variable supply was needed to give flexibility during amplifier testing. T3 is a variable voltage auto transformer or 'Variac' which allows adjustment of the ht from 0 to 3000V. It also provides optimum adjustment of the linear amplifier output.

T4 is the main high voltage transformer with 240V primary and 1100V + 1100V secondary. It is a modified low voltage transformer which was conservatively rated at 1·3kVA continous duty by the manufacturer. Having first established that the voltage per turn was 1·01 with 240V input, the laminations were dismantled and the secondary winding removed. There was a copper screen between the primary and secondary which was left in place. One end of the former was trimmed down to the copper screen and the primary was boxed-in using paxolin sheet and epoxy resin. This provided a uniform section to accept two rectangular bobbins of approximately one third the total width of the primary winding. The narrow bobbins eliminated the need for insulation between winding layers. The two bobbins were wound with 1100 turns each of 0·6mm (24swg) enamelled copper wire and the transformer reassembled with spacers between the secondary bobbins, leaving gaps for air circulation. The transformer was finished off by applying a liberal coat of transformer was finished off by applying a liberal coating of transformer varnish to the windings.

A high voltage bridge rectifier D20 to D51 was made from 1000V PIV diodes, series connected with voltage equalizing resistors. They were mounted between tag strips on nylon standoff insulators. Smoothing capacitors were also series connected with voltage equalizing resistors and although 1000uF 450V capacitors were used. Other combinations may be chosen as long as the final capacitance bank is at least 50uF.

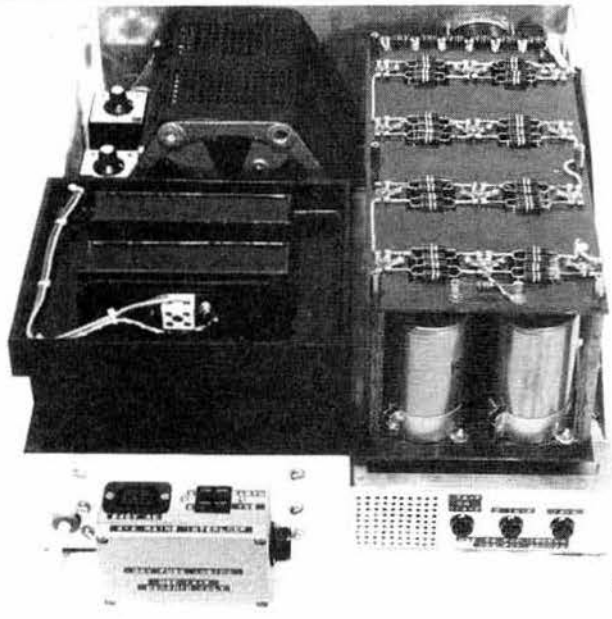
There are four resistors across each capacitor. This was a precaution to ensure that if one of the resistors became open circuit, the voltage across the electrolytic would not exceed its rated value. This may appear over cautious but having witnessed the explosion of an electrolytic capacitor I decided that it was better to be safe than sorry.

The resistor chain R48 to R54 is to enable a 300V meter, M3, to monitor 0 to 3000V. Other meters would be suitable but the movement should not be greater than 1mA FSD. Resistors R87 to R91 are an essential part of the fault protection circuit and under no circumstances should they be omitted. They serve to reduce the maximum fault current to 68A.

F6 is a ceramic sand filled cartridge fuse which is cheaper and easier to obtain than higher voltage types. It is rated at 415V ac and 10kA breaking capacity. The circuit has been fault tested using a number of these fuses from different sources and I am satisfied that it will achieve fast reliable disconnection at 3000V 68A peak current.

From a safety point of view I would not normally use a fuse outside the manufacturer's stated rating unless there was additional protection, and in this circuit there is a fuse (F5) in the primary of the ht transformer.

To prove that F5 was adequate backup protection, a link was placed across F6 and the output was shorted to ground. There was a much higher surge current than that recorded on the previous test, but none of the components were damaged. It must be emphasised that these fault tests were carried out using specialised equipment and facilities so, for safety reasons, it is not recommended that you repeat them. ▶



HT power supply showing main components

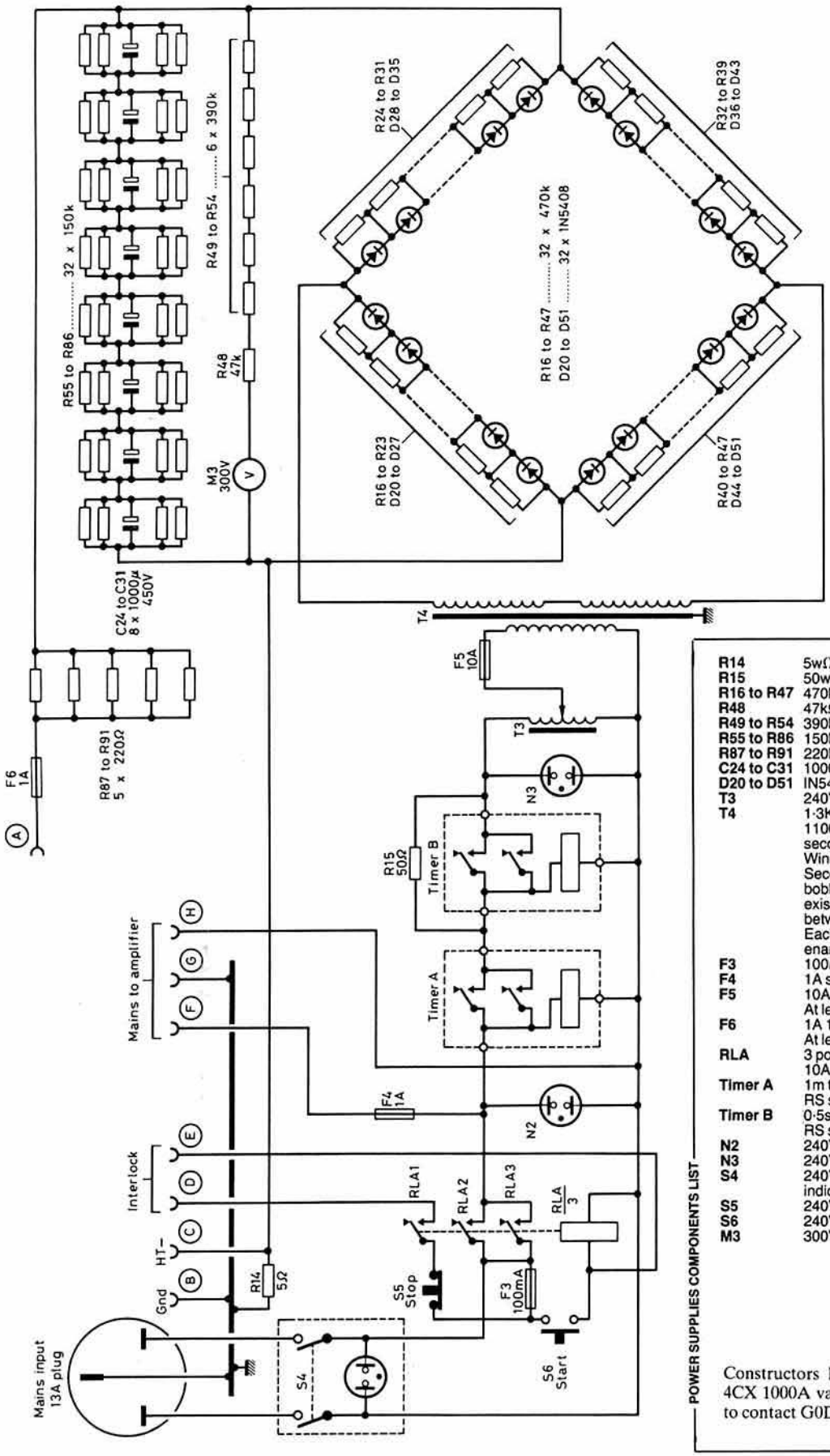
components were damaged. It must be emphasised that these fault tests were carried out using specialised equipment and facilities so, for safety reasons, it is not recommended that you repeat them.

Relay changeover circuit

A diagram for the transmit/receive changeover circuit is shown in Fig 7. RLB and RLC are coaxial relays with 24/28V coils. RLD is a 24V miniature relay with 250V, 1A contacts. It operates both coaxial relays and the standby circuit. PTT is connected to the normally open contacts on the auxiliary output of a transceiver.

Testing and setting up

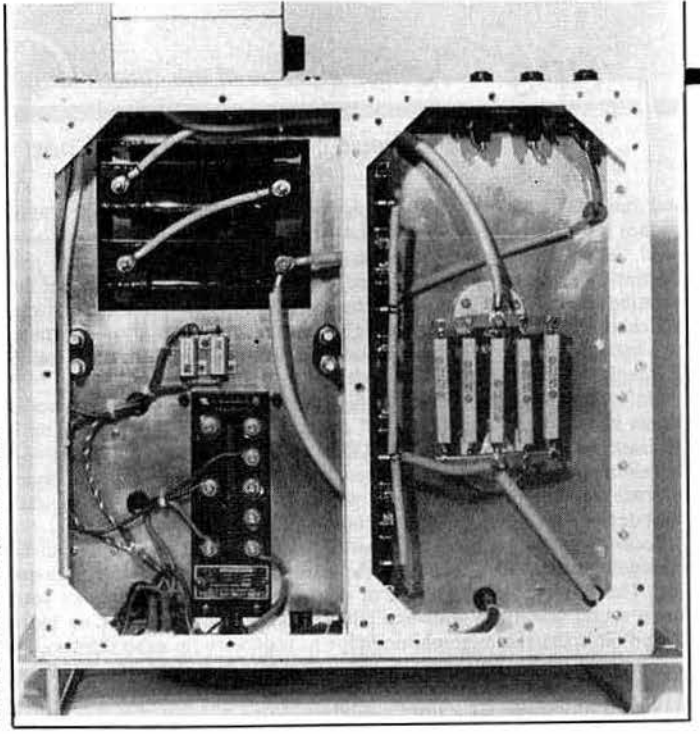
A dummy load is essential for the testing of this amplifier. You will also requre an accurate digital multirangemeter, 0-1A ammeter, 0-3000V voltmeter, two-tone audio generator, two product detectors with potential divider, oscilloscope (preferably with X and Y inputs), 100W power/swr meter, 1000W power/swr meter and a suitable multimode ssb transceiver.



POWER SUPPLIES COMPONENTS LIST

R14	5wΩ 5W wire wound
R15	50wΩ 50W wire wound
R16 to R47	470kΩ 1W
R48	47kΩ 1W
R49 to R54	390kΩ 1W
R55 to R86	150kΩ 2W
R87 to R91	220kΩ 17W wire wound
C24 to C31	1000uF 450V electrolytic
D20 to D51	IN5408
T3	240V, 8A Variac
T4	1·3KVA transformer, 240V primary 1100V + 1100V secondary. Winding details for 1V/turn transformer: Secondary – two 35mm wide fabricated bobbins, mounted side by side over existing primary with ventilation gaps between. Each bobbin contains 1100t, 0·6mm(24swg) enam copper wire – See text.
F3	100mA fast blow fuse
F4	1A slow blow fuse
F5	10A 1·25in H.R.C sand filled ceramic fuse. At least 10kA breaking capacity at 415Vac.
F6	1A 1·25 H.R.C sand filled ceramic fuse. At least 10kA breaking capacity at 415VAc.
RLA	3 pole changeover relay. 10A, 250V contacts, 240V coil
Timer A	1m to 30m time delay relay RS stock no 347-927 or similar.
Timer B	0·5s to 20s time delay relay RS stock no 349-872 or similar.
N2	240V orange neon indicator
N3	240V green neon indicator
S4	240V 13A double pole rocker switch with neon indicator.
S5	240V 1A push-to-make switch
S6	240V 1A push-to-break switch
M3	300V, 1kΩ/V moving coil meter.

Constructors having difficulty in obtaining tested 4CX 1000A valves or other components are invited to contact G0DXU direct for further information.



Under-side of the ht power supply

Before applying any supply voltages to the amplifier, connect a low level rf source to the input socket via an swr meter and apply the minimum power necessary to achieve a reliable swr reading on the 28MHz band. Adjust C32 and if necessary lengthen or shorten the coil to achieve the lowest swr reading. Next, check that the ht supply is functioning correctly with the amplifier disconnected. Short the interlock terminals (D) to (E) and set the variac T3 for zero voltage. Adjust timer A to give a five minute delay and timer B to give a 10 seconds delay. Gradually rotate the variac control to check the no-load ht voltage, noting the ht panel meter reading against an accurate 3000V voltmeter connected to the ht output.

It is worthwhile carrying out a short-circuit test. First make sure that the capacitors have fully discharged and the variac is at zero setting, then short the ht output to ground through a 0-1 A ammeter. Switch on and wait for the timers to operate then gradually rotate the variac control until the ammeter reads 0·5A and leave for a few minutes to check that no components are overheating. Without moving the variac, disconnect the ammeter to monitor the open circuit voltage, which should be less than 200V. The lower this figure, the better the regulation will be under full load conditions.

Having completed tests on the ht power supply, remove the valve from its socket, connect the amplifier and check that the bias voltage is around −150V. This will ensure that the valve will be correctly biased into an off state. The valve can now be replaced and checks can be made on the heater and screen supplies. Also, ensure that there is adequate pressure in the grid compartment by the water manometer method mentioned earlier.

When you are satisfied that all supplies are functioning correctly, set RV1 to maximum bias voltage (slider to D16) and gradually raise the ht voltage to 1500V, then connect (K) to ground. Reduce the grid bias voltage with RV1 until the ht current is about 0·25A. Raise the ht voltage to 2500V and check the screen current which should be about −6mA (this will vary depending on the valve). Reduce the grid bias voltage further until the anode current reaches 0·4A (it will be necessary to readjust the ht voltage to allow for voltage drop under load). Monitor the screen current which should be approximately −10mA. The valve will now be dissipating 1kW, so ensure that the hot air from the anode compartment is not obstructed or allowed to circulate back into the blower inlet. Remember to wait at least five minutes after placing the amplifier on standby before switching off to allow adequate cooling of the valve. The amplifier is now ready for rf tests.

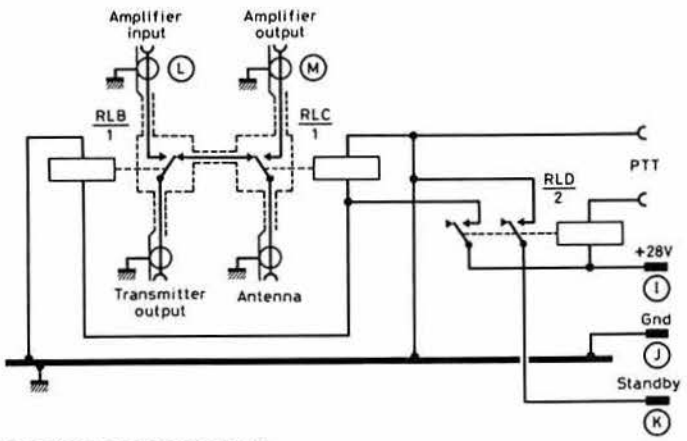


Fig 7. Relay changeover circuit

Connect the relay changeover circuit, dummy load, power attenuator (if needed) and the driver transmitter. Power meters should also be connected to the input and output of the amplifier. At this stage you should check the amplifier for parasitic oscillations. The test is carried out without rf drive and involves checking for sudden fluctuations in grid current, screen current and any indication of rf on the power meters. The valve should be running at its maximum dissipation (0·4A 2500V) and all bands need to be checked at various settings of the 'tune' and 'load' capacitors. The 4CX1000A should not require parasitic suppression. Having established that the amplifier has good stability and is completely free from parasitic problems, you can then proceed to the next stage.

Set the amplifier to 3·5MHz and the 'tune' and 'load' capacitors C11 and C12 to maximum, then adjust the ht to 2500V. Gradually increase the rf input power to 2W, observing the increase in negative screen current. Tune the amplifier until a peak is observed on the output meter. Continue to increase the input power and monitor the screen current which will continue to dip then reach a point where it reverses. Further power increase will make the screen current rise rapidly and eventually become positive. Stop when you reach zero current. Observe the power output which will probably be about 800W with 20W input. Reduce the 'Load' capacitance, re-tune then increase input power until the screen current again reaches zero. This procedure should be repeated until maximum output power is obtained. It is advisable to rest the amplifier in standby mode every few minutes to allow it to cool. You may have observed that the screen current peaks with the maximum power when tuning. During operation of the amplifier I use the screen current meter as a tuning indicator. Repeat the above testing procedure on all bands and note the 'tune' and 'load' dial readings. These may be useful later if repeat tests are necessary.

Having established that the amplifier will operate reliably at high power levels, you should now check linearity. If you own or are able to borrow an oscilloscope with separate X and Y inputs it is advisable to use this to monitor linearity with a two tone input. Connect the X channel via an envelope detector and potential divider to the amplifier input then the Y channel via a second envelope detector and potential divider to the amplifier output. An alternative method is to monitor directly the output envelope produced by a two tone input. Having used both methods I find the former to be more exacting as it is easier to assess the straightness of a line than the shape of a sine wave.

As before, start with the 3·5MHz band and after tuning the amplifier, observe the display on the oscilloscope. Assuming you use the straight line method, there should be no curves or kinks if the amplifier is tuned and functioning correctly. If the line is distorted then there are three main reasons: a steadily steepening curve indicates insufficient standing anode current. An opposite curve probably means that there is a problem with the screen or grid regulation. Flattening at the top will result if the amplifier is overdriven. If you are not familiar with the techniques of checking linearity, it is advisable to consult RSGB or ARRL handbooks and '*Single Sideband Principles and Circuits*' by E W Pasppenfus – published by the Mc Graw-Hill Book Co.

Having thoroughly checked the amplifier at high power levels you can be confident that there will be trouble free operation when it is coasting along at the full legal limit. The ideal ht voltage for normal use is 1800V. Adjust to give 400W into the dummy load with a single tone input. This will require 18W of drive (or 72W through the power attenuator). Switch to the two tone input and check the linearity. If you use an rf ammeter in series with the 50Ω dummy load, 2·0A will equate to 400W pep. This is half the current observed on the single tone test because the mean power of an undistorted two tone envelope is exactly half the peak. The standing anode current may be reduced to 200mA with negligible effect on linearity, but I would not recommend that it was reduced further as this will degrade the otherwise excellent performance of this amplifier. ■